



PORTLAND HARBOR RI/FS
FIELD SAMPLING PLAN
TRANSITION ZONE WATER SAMPLING

ADDENDUM 2
SAMPLING PLANS FOR KINDER MORGAN
LINNTON, ARCO, RHONE POULENC,
WILLBRIDGE, AND GUNDERSON

March 27, 2006

Prepared for
The Lower Willamette Group

Prepared by
Integral Consulting Inc.

TABLE OF CONTENTS

TABLE OF CONTENTS.....	i
LIST OF FIGURES	iii
LIST OF TABLES	v
LIST OF ACRONYMS	vi
FOREWORD	vii
1. INTRODUCTION	1
2. KINDER MORGAN LINNTON	3
2.1. Site Hydrogeology and COI Migration.....	3
2.2. Round 2 Groundwater Discharge Mapping	4
2.2.1. Stratigraphic Coring Results	4
2.2.2. Trident Results	4
2.2.3. Seepage Meter Results	5
2.2.4. Discharge Mapping Summary	5
2.3. Transition Zone Water and Bulk Sediment Sampling Plan	6
3. ARCO TERMINAL 22T	7
3.1. Site Hydrogeology and COI Migration.....	7
3.2. Round 2 Groundwater Discharge Mapping	8
3.2.1. Stratigraphic Coring Results	8
3.2.2. Trident Results	8
3.2.3. Seepage Meter Results	10
3.2.4. Discharge Mapping Summary	10
3.3. Transition Zone Water and Bulk Sediment Sampling Plan	11
4. RHONE POULENC	13
4.1. Site Hydrogeology and COI Migration.....	13
4.2. Round 2 Groundwater Discharge Mapping	13
4.2.1. Stratigraphic Coring Results	14
4.2.2. Trident Results	14
4.2.3. Seepage Meter Results	15
4.2.4. Screening Sample Results	15
4.2.5. Discharge Mapping Summary	16
4.3. Transition Zone Water and Bulk Sediment Sampling Plan	16
5. WILLBRIDGE	18
5.1. Site Hydrogeology and COI Migration.....	18
5.2. Round 2 Groundwater Discharge Mapping	19
5.2.1. Stratigraphic Coring Results	19
5.2.2. Trident Results	20
5.2.3. Seepage Meter Results	21
5.2.4. Discharge Mapping Summary	21

5.3. Transition Zone Water and Bulk Sediment Sampling Plan	21
6. GUNDERSON	23
6.1. Site Hydrogeology and COI Migration	23
6.2. Round 2 Groundwater Discharge Mapping	24
6.2.1. Stratigraphic Coring Results	24
6.2.2. Trident Results	24
6.2.3. Seepage Meter Results	25
6.2.4. Screening Sample Results	26
6.2.5. Discharge Mapping Summary	26
6.3. Transition Zone Water and Bulk Sediment Sampling Plan	26
7. REFERENCES	28

LIST OF FIGURES

- Figure 2-1. Kinder Morgan Potentiometric Surface and Cross Section Location Map
- Figure 2-2a–b. Kinder Morgan Geologic Cross Sections
- Figure 2-3a–e. Kinder Morgan Upland Groundwater COIs
- Figures 2-4a–f. Kinder Morgan COI Cross Sections
- Figures 2- 5a–f. Kinder Morgan Stratigraphic Core Results
- Figure 2-6. Kinder Morgan Trident Temperature Mapping Results
- Figure 2-7. Kinder Morgan Trident Conductivity Mapping Results
- Figures 2-8a–b. Kinder Morgan Seepage Meter Data
- Figure 2-9. Kinder Morgan Transition Zone Water Sampling Locations
-
- Figure 3-1. ARCO Potentiometric Surface and Cross Section Location Map
- Figures 3-2a–c. ARCO Geologic Cross Sections
- Figures 3-3a–e. ARCO Upland Groundwater COIs
- Figures 3-4a–i. ARCO COI Cross Sections
- Figures 3-5a–g. ARCO Stratigraphic Core Results
- Figures 3-6a. ARCO Trident Temperature Mapping Results from Pilot Study
- Figures 3-6b. ARCO Trident Conductivity Mapping Results from Pilot Study
- Figure 3-7. ARCO Trident Temperature Mapping Results
- Figure 3-8. ARCO Trident Conductivity Mapping Results
- Figures 3-9a–b. ARCO Seepage Meter Data
- Figure 3-10. ARCO Transition Zone Water Sampling Locations
-
- Figure 4-1. Rhone Poulenc Potentiometric Surface and Cross Section Location Map
- Figures 4-2a–c. Rhone Poulenc Geologic Cross Sections
- Figures 4-3a–f. Rhone Poulenc Upland Groundwater COIs
- Figures 4-4a–l. Rhone Poulenc COI Cross Sections
- Figures 4-5a–i. Rhone Poulenc Stratigraphic Core Results
- Figure 4-6. Rhone Poulenc Trident Temperature Mapping Results
- Figure 4-7. Rhone Poulenc Trident Conductivity Mapping Results
- Figures 4-8a–c. Rhone Poulenc Seepage Meter Data

- Figure 4-9. Rhone Poulenc Screening Sample Results
- Figure 4-10. Rhone Poulenc Transition Zone Water Sampling Locations
-
- Figure 5-1. Willbridge Potentiometric Surface and Cross Section Location Map
- Figures 5-2a–b. Willbridge Geologic Cross Sections
- Figures 5-3a–e. Willbridge Upland Groundwater COIs
- Figures 5-4a–f. Willbridge COI Cross Sections
- Figures 5-5a–f. Willbridge Stratigraphic Core Results
- Figure 5-6. Willbridge Trident Temperature Mapping Results
- Figure 5-7. Willbridge Trident Conductivity Mapping Results
- Figures 5-8a–b. Willbridge Seepage Meter Data
- Figure 5-9. Willbridge Transition Zone Water Sampling Locations
-
- Figure 6-1. Gunderson Potentiometric Surface and Cross Section Location Map
- Figures 6-2a–c. Gunderson Geologic Cross Sections
- Figures 6-3a–h. Gunderson Upland Groundwater COIs
- Figures 6-4a–d. Gunderson COI Cross Sections
- Figures 6-5a–c. Gunderson Stratigraphic Core Results
- Figure 6-6. Gunderson Trident Temperature Mapping Results
- Figure 6-7. Gunderson Trident Conductivity Mapping Results
- Figures 6-8a–b. Gunderson Seepage Meter Data
- Figure 6-9. Gunderson Screening Sample Results
- Figure 6-10. Gunderson Transition Zone Water Sampling Locations

Supplemental Figures

- Figure SAIC 2. Chevron Willbridge Historic Site Features (Location of Willbridge Slough)

LIST OF TABLES

Table 2-1.	Kinder Morgan Trident Data Set
Table 2-2.	Transition Zone Water and Sediment Sampling Plan Summary for the Kinder Morgan Site
Table 3-1.	ARCO Trident Data Set
Table 3-2.	Transition Zone Water and Sediment Sampling Plan Summary for the ARCO Site
Table 4-1.	Rhone Poulenc Trident Data Set
Table 4-2.	Rhone Poulenc Screening Sample Results
Table 4-3.	Transition Zone Water and Sediment Sampling Plan Summary for the Rhone Poulenc Site
Table 5-1.	Willbridge Trident Data Set
Table 5-2.	Transition Zone Water and Sediment Sampling Plan Summary for the Willbridge Site
Table 6-1.	Gunderson Trident Data Set
Table 6-2.	Gunderson Screening Sample Results
Table 6-3.	Transition Zone Water and Sediment Sampling Plan Summary for the Gunderson Site

LIST OF ACRONYMS

BTEX	benzene, toluene, ethylbenzene, xylenes
COIs	chemicals of interest
DCA	dichloroethene
DCE	dichloroethane
DNAPL	dense nonaqueous phase liquid
FSP	field sampling plan
LNAPL	light nonaqueous phase liquid
MTBE	methyl-tert-butyl ether
PAHs	polycyclic aromatic hydrocarbons
QC	quality control
QAPP	quality assurance project plan
RI/FS	remedial investigation and feasibility study
SAP	sampling and analysis plan
TCA	trichloroethane
TCE	trichloroethene
TPH	total petroleum hydrocarbons
VOCs	volatile organic compounds

FOREWORD

This document is Addendum 2 to the Transition Zone Water Field Sampling Plan (Integral 2005b), which is Attachment 2 to the Round 2 Groundwater Pathway Assessment Sampling and Analysis Plan (Integral et al. 2005). This addendum presents the site-specific sampling plans for collection of transition zone water samples from sediments in zones of potential discharge of groundwater chemical of interest offshore of five sites along the Willamette River – Kinder Morgan Linnton, ARCO, Rhone Poulenc, Willbridge, and Gunderson. This final draft of Addendum 2 has been prepared following completion of the subject field work (completed December 2, 2005) to provide a complete and final document, which reflects the modifications to the sampling effort agreed upon for conditional approval by EPA and its agency partners. This conditional approval to proceed with the field work was provided on October 13, 2005 (EPA 2005).

1. INTRODUCTION

This document is an addendum to the Transition Zone Water Field Sampling Plan (FSP; Integral 2005b), which is Attachment 2 to the Round 2 Groundwater Pathway Assessment Sampling and Analysis Plan (SAP; Integral et al. 2005). This addendum presents the site-specific sampling plans for collection of transition zone water samples from sediments in zones of potential discharge of groundwater chemical of interest (COI) offshore of five sites along the Willamette River – Kinder Morgan Linnton, ARCO, Rhone Poulenc, Willbridge, and Gunderson.

This sampling will be conducted to support the Round 2 Groundwater Pathway Assessment for the Portland Harbor remedial investigation and feasibility study (RI/FS). Specific sampling methods and quality control protocols for the sampling and analyses are described in the FSP (Integral 2004) and the Supplement to Addendum 3 to the Quality Assurance Project Plan (QAPP; Integral 2005d).

Sampling plans for each site were developed based on consideration of multiple lines of evidence regarding potential areas of groundwater plume discharge, specifically:

- In-water temperature and conductivity mapping using the Trident Probe
- In-water seepage meter measurements
- Nature and extent of COIs in upland groundwater
- Groundwater flow gradients (horizontal and vertical)
- Upland and in-water stratigraphy
- Surface sediment texture mapping
- Transition-zone water COI concentrations from screening samples collected during the discharge mapping effort (selected sites only)
- Available bulk sediment chemistry data
- Available bulk sediment toxicity data.

The August and September 2005 findings of the groundwater discharge mapping effort are presented for each site, along with relevant additional supporting information. The groundwater discharge mapping effort included stratigraphic coring, transect-based discharge mapping (temperature and conductivity measurement using the Trident Probe), collection of screening samples of transition zone water at select sites, and discharge verification measurement using seepage meters. The scope and methods of the groundwater discharge mapping effort are detailed in the Groundwater Discharge Mapping FSP (Integral 2005a), which is Attachment 1 to the SAP. To identify probable zones of groundwater discharge, the groundwater discharge mapping data are evaluated in the context of site upland and in-water hydrogeologic and chemical data, which are described in the SAP (Integral et al. 2005). Additional site-specific background information is presented in detail in

Appendix A of the SAP. Sampling plans for the other four sites identified in the SAP and Transition Zone Water FSP (ExxonMobil, Gasco, Siltronic, and Arkema) are provided in the first addendum to the FSP (Integral 2005c).

The following sections present the transition zone water sampling plans for each of the five sites and include a summary of the results of the discharge mapping findings, a map of the planned transition-zone water sample locations, and a table summarizing sample counts, target sampling depth intervals, and COIs to be analyzed. In addition, each section discusses the rationale supporting the selection of the proposed sampling locations for each site.

2. KINDER MORGAN LINNTON

2.1. SITE HYDROGEOLOGY AND COI MIGRATION

The Kinder Morgan Linnton site is an operating bulk fuel storage facility located on the west bank of the Willamette River at approximately river mile 4 (Figure 2-1). The site is underlain by a single, unconfined aquifer. Groundwater, present in the alluvium underlying the surficial fill, has a general flow direction toward the river in the nearshore areas. Figures 2-1, 2-2a, and 2-2b depict the potentiometric surface in the shallow water-bearing zone and the geologic cross sections. The water table is influenced by the active interim remedial action measure, which consists of five groundwater recovery wells (identified on Figure 2-3a) near the center of the site. A tiered timber seawall is also present over the entire shoreline of the site; however, it is not expected to bound groundwater flow. Four intermittent seeps have been observed at the locations shown on Figure 2-1.

Primary COIs in groundwater are those commonly associated with hydrocarbon releases, including benzene, toluene, ethylbenzene, xylenes (BTEX), total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), and several metals. Figure 2-3a presents the approximate extent of light nonaqueous phase liquid (LNAPL) at the site. Figures 2-3b–e depict concentrations of total PAHs, total BTEX, lead, and arsenic in shallow groundwater. Figures 2-4a–f present the most recent groundwater concentration data¹ for upland wells on Kinder Morgan cross-sections. Although dissolved-phase COIs are present in groundwater over much of the Kinder Morgan site, BTEX and PAHs are most predominantly associated with groundwater beneath and downgradient of the LNAPL.

Based on this understanding of the site, potential discharge areas for groundwater-related COIs to the Willamette River include the nearshore areas along the shoreline, via flow under and/or through the seawall, particularly in the area adjacent to the LNAPL source area. In addition, there is a potential pathway for groundwater COI discharge to the river through the shallow sand to silty sand in the areas beyond the northern and southern extents of the seawall.

Findings of the discharge mapping work, performed to further investigate groundwater discharge to the river, are presented in the following section. A detailed discussion of the Kinder Morgan Linnton site is presented in Appendix A-1 of the SAP (Integral et al. 2005).

¹ Note: All data for the cross-section plots were taken from Appendix A of the Groundwater Pathway Assessment SAP (Integral et al. 2005).

2.2. ROUND 2 GROUNDWATER DISCHARGE MAPPING

The groundwater discharge mapping effort at the Kinder Morgan site included stratigraphic coring, transect-based discharge mapping (temperature and conductivity measurement using the Trident Probe), and discharge verification measurements using seepage meters.

2.2.1. Stratigraphic Coring Results

A total of four stratigraphic cores (plus one replicate core) were collected offshore of the Kinder Morgan site to improve the understanding of the offshore stratigraphy. The location of the cores is shown on Figure 2-5a. Core logs are presented on Figures 2-5b–f. Core logs C2, C2-2, and C3 show a relatively thin silt layer overlying the basalt bedrock. Core logs C1 and C4, located downstream and upstream of the other cores, respectively, indicate a thicker layer of silt with layers of sandier material over the basalt. Core C3 stratigraphic information was added to cross-section D1-D1', shown on Figure 2-2b. The resulting cross-section is consistent with the surface sediment texture, indicating nearshore silt and zones of mixed sand and silt farther offshore (as shown in Figures 2-6 and 2-7 and discussed below).

2.2.2. Trident Results

The Trident Probe temperature and conductivity data, as well as relevant field observations (e.g., sediment texture), are summarized in Table 2-1. Temperature and conductivity mapping locations and results are shown on Figures 2-6 and 2-7. The groundwater discharge mapping effort spanned the entire shoreline, extending both upstream and downstream of the site boundaries. The sediment texture offshore of the Kinder Morgan site was also recorded at each Trident location based on the resistance felt by the operators during the installation of the Trident Probe (Table 2-1). Confirmation surface sediment core samples (1-2 ft) were collected at four of the 54 successfully completed Trident measurement locations to verify the operator observations. In addition, at 12 locations, the sediment was found to adhere to the probe upon removal, and the sediment texture was subsequently recorded. Measurements could not be made at 12 of the planned Trident locations due to inaccessibility within the dense pier structure. A transect (KM15) was added in the field to collect additional information in response to this access limitation.

Figures 2-6 and 2-7 present the interpreted distribution of offshore sediment textures based on Trident observations, grab samples, and past sediment sampling events. In general, the nearshore area consists of silt extending from the upstream end of the site to cover roughly two-thirds of the shoreline. At the upstream end of the site, the silt becomes somewhat sandier farther offshore. Silt was also observed at Trident locations just offshore of the outer dock along the full extent of the dock structure. Over the downstream third of the site, clay was observed in the nearshore area extending downstream to the property line. Downstream of the property line, surficial sand was observed in the nearshore area.

Figures 2-5 and 2-6 also present the Trident Probe results. Temperature (°C) and conductivity (mS/cm) data are presented as the difference between simultaneous readings in the river water column (taken 30 cm above the sediment mudline) and the saturated sediment (taken 60 cm below the sediment mudline). The Kinder Morgan Trident data indicate several general patterns. The clay-covered area, located within the northern portion of the dock structure and in the silt areas shoreward of the dock structure, showed generally minimal temperature signals (low temperature differences), with a few exceptions (KM15-A, KM8-A, KM10-A, and KM11-B). In response, seepage meters were placed at KM8-A and KM11-B. In the sandy area just downstream of the site, only KM2-E showed a strong temperature signal. To assess the sand and possible effect of mixing between groundwater and surface water in these coarser sediments, seepage meters were placed at KM1-B and KM2-E. Just offshore of the dock structure, Trident measurements show stronger temperature signals. This is consistent with observations in silty zones at other sites, including those observed during the Pilot Study, as reported in the Discharge Mapping FSP (Integral 2005a). To further evaluate this zone, seepage meters were placed at KM15-C and KM10-D. Finally, the mixed silt and sand zone farther offshore of site showed some temperature variation, and a seepage meter was placed at KM12-D, where both the temperature and conductivity signals were relatively strong.

2.2.3. Seepage Meter Results

Seepage meters capable of recording time-series positive and negative flux were installed at seven of the Trident locations offshore of the Kinder Morgan site: KM1-B, KM2-E, KM8-A, KM10-D, KM11-B, KM12-D, and KM15-C. These seepage meter locations are designated as KMSEEP 1B, KMSEEP 2E, KMSEEP 8A, KMSEEP 10D, KMSEEP 11B, KMSEEP 12D, and KMSEEP 15C. Complete results of the seepage meter measurements are presented in Figure 2-8; average and maximum observed fluxes at each location are also shown on Figures 2-6 and 2-7. Seepage meter flow averages were close to zero or slightly negative for all but one location: KMSEEP 8A. The positive seepage observed at this nearshore area location is consistent with the conceptual model of groundwater discharge from the site, and suggests a possible pathway in the area near the wooden seawall through the sandy fill material. Low net positive flow was also observed at KMSEEP 11B.

2.2.4. Discharge Mapping Summary

The combined lines of evidence suggest that the shallow groundwater and associated COI discharge are likely occurring primarily in the nearshore area adjacent to the LNAPL plume. The nearshore sand and clay areas at the downstream end of the site, as well as the silty zone offshore of the dock area, do not show evidence of groundwater discharge. Seepage meter results also showed no evidence of groundwater discharge through the offshore mixed sand and silt areas, located closer to shore in the upstream area of the site.

2.3. TRANSITION ZONE WATER AND BULK SEDIMENT SAMPLING PLAN

Figure 2-8 presents the planned transition zone water sampling locations. A total of eight transition zone water samples will be collected from six locations. At each location, a sample will be collected within the top 30 cm of the sediments. A second sample will be collected from a target depth of at least 90 cm (up to 150 cm, if possible) at two of the locations. The rationale for the sampling locations is as follows:

- Samples will be collected from four locations at the nearshore area adjacent to the LNAPL plume. These sampling locations are labeled R2-KM-1, KM-06-A, KM-08-A, and KM-10-A. Paired samples at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be collected at KM-08-A, where the high average seepage meter discharge rate was observed.
- A sample will also be collected at KM-11-B, where there was a relatively strong temperature signal and the seepage meter results showed a small, but positive, average discharge.
- Samples will also be collected within the offshore zone of surficial mixed sand and silt, at location R2-KM-2. Sampling in this location will evaluate whether there is a pathway of more conductive material that extends from this mixed zone upgradient to upland groundwater COIs. A paired sample at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be collected at this location, which is offshore of the central area of the LNAPL plume.

It is anticipated that the majority of the samples will be collected using the Trident Probe. Small-volume peepers will be used at any 30 cm sampling locations where the recovery (flow and/or volume) of the transition zone water by the Trident Probe is found to be inadequate. Replicate and equipment blank quality control (QC) samples will be collected in accordance with the specifications prescribed in the QAPP supplement (Integral 2005d).

Figure 2-9 also depicts the locations where bulk sediment samples will be collected (KM-08-A and R2-KM-2) to address sediment characterization data gaps in the vicinity of transition zone water sampling locations. The sediment samples will be collected from transition zone water sampling locations where bulk sediment chemistry data are not available for a similar sediment type located within approximately 50 ft, or where there is the potential for a more localized discharge (e.g., KM-08-A near Seep04). Round 2 sediment sampling locations are shown on Figure 2-9 for reference, and locations where volatile organic compound (VOC) analyses and/or toxicity bioassays were conducted are indicated in unique colors.

Table 2-2 summarizes the analytes for the transition zone water and sediment samples.

3. ARCO TERMINAL 22T

3.1. SITE HYDROGEOLOGY AND COI MIGRATION

ARCO Terminal 22T (ARCO) is an operating bulk fuel storage facility located on the western shore of the Willamette at approximately river mile 4.9 (Figure 3-1). Geologic cross-sections of the site are shown on Figures 3-2a–c. Groundwater flow at the ARCO site occurs primarily in the surficial fill layer that underlies the site and consists of sand and sandy gravel. The fill layer is underlain by an alluvial deposit that transitions with depth from finer-grained silty materials to sandier materials, and generally forms two layers: an overlying fine-grained alluvium, and an underlying sandy alluvium. The alluvium is underlain by basalt bedrock.

A west-east trending, buried erosional channel is present beneath the middle of the site (Figures 3-2a–b). This feature cuts into the fine-grained alluvium layer and is filled with coarser channel-fill material (sand and gravel). The more permeable materials of the buried erosional feature represent a preferential pathway for groundwater flow. It is unclear if the channel cuts entirely through the fine-grained alluvium layer and into the sand alluvium below. Some borings in this area (e.g., GP-5) suggest that the channel fill materials are underlain by sand/silty-sand materials that are somewhat coarser than the silt/clays that predominantly make up the fine-grained alluvium elsewhere on the site.

Figures 3-3a–e depict the extent of LNAPL and concentrations of total PAHs, petroleum hydrocarbons, total BTEX, and several metals in shallow groundwater across the site. Figures 3-4a–l present the most recent groundwater concentration data² for upland wells on ARCO cross-sections. Concentrations of dissolved-phase COIs in groundwater are highest in the immediate vicinity of and downgradient from two primary LNAPL source areas at the ARCO site. The first is located in the sand and gravel deposits of the buried erosional channel near the center of the site. The second LNAPL area is located in an area north of the site beyond the northern extent of the seawall, which extends to the property boundary. Additionally, COI concentrations are relatively high in the area between the two LNAPL sources.

Across much of the site, the seawall and extraction wells operating along the site shoreline limit the potential for LNAPL and dissolved-phase COIs in groundwater to migrate from upland areas to the river. However, there are still possible paths for groundwater to reach the river. The seawall is not keyed into the fine-grained alluvium, so there is some possibility that dissolved groundwater COIs may migrate toward the river beneath the wall. In addition, a residual “detached” plume may be present east of the seawall. Also, portions of the plume associated with the northern LNAPL source area are located beyond the northern extent of the seawall and

² Note: All data for the cross-section plots were taken from Appendix A of the Groundwater Pathway Assessment SAP (Integral et al. 2005).

extraction well system and may migrate to the river. Finally, groundwater and/or LNAPL seepage through cracks in the seawall at times of high groundwater levels may represent a complete transport pathway to the river.

Findings of the discharge mapping work, performed to further investigate groundwater discharge to the river, are presented in the following section. A detailed discussion of the ARCO site is presented in Appendix A-2 of the SAP (Integral et al. 2005).

3.2. ROUND 2 GROUNDWATER DISCHARGE MAPPING

The groundwater discharge mapping effort at the ARCO site included stratigraphic coring, transect-based discharge mapping (temperature and conductivity measurements using the Trident Probe), and discharge verification measurements using seepage meters.

3.2.1. Stratigraphic Coring Results

A total of six stratigraphic cores were collected offshore of the ARCO site to improve the understanding of the offshore hydrogeology. The location of the cores is shown on Figure 3-5a. Core logs are presented on Figures 3-5b–g. The stratigraphic information collected from each of the cores is generally consistent, with each showing a predominately silty surficial layer, overlying a predominantly sandy layer. These layers are consistent with the alluvial deposit that underlies the uplands surficial fill zone beneath the site. Gravel basalt was encountered at depths ranging from 25 to 35 ft below the mudline at locations GW2-A3, GW2-A4, GW2-A5, and GW2-A6. Core logs for locations GW2-A1, GW2-A2, and GW2-A5 are incorporated into geologic cross-section Figures 3-2b–c.

Petroleum odors were noted in cores GW2-A1 and GW2-A2 from the surface to depths of 18 ft and 14 ft below the mudline, respectively. In addition, at location GW2-A2 a 1-ft-thick sand layer observed at a depth of 10-11 ft was noted to have a slight petroleum odor and a light sheen. A similar, possibly connected thin layer of sand was also observed in the core from the farther offshore location GW2-A1, at a depth of 13 ft below the mudline. A strong petroleum odor was noted in the sand layer at this location, though no sheen was present. No petroleum odor or sheen was observed in cores GW2-A3 and GW2-A4. Petroleum odors were, however, observed in cores GW2-A5 and GW2-A6 from the surface to depths of 8 ft and 7 ft below the mudline, respectively.

3.2.2. Trident Results

Trident temperature and conductivity discharge mapping was completed at the ARCO site both during the fall 2004 Groundwater Pathway Assessment Pilot Study and during the summer 2005 Round 2 groundwater pathway assessment field effort. The pilot study Trident mapping took place in the vicinity of the site dock area—centering

on the area offshore of the buried channel and primary LNAPL source area. The 2005 mapping effort primarily focused on the northern end of the site, offshore of the second LNAPL source area. Combined, the two mapping efforts span the entire shoreline of the site.

The 2004 Trident mapping results are described in detail in the Pilot Study Data Report (Appendix B of the SAP; Integral et al. 2005) and are summarized in Figures 3-6a–b. The 2005 Trident Probe temperature and conductivity data, as well as relevant field observations (e.g., sediment texture), are summarized in Table 3-1. The 2005 Trident temperature and conductivity mapping locations and results are shown on Figures 3-6a–b. The sediment texture offshore of the ARCO site was also recorded at each Trident location based on the resistance felt by the operators during the installation of the Trident Probe (Table 3-1 summarizes the 2005 results). During the 2005 event, confirmation surface sediment core samples (1-2 ft) were collected at four of the 30 successfully completed Trident Probe locations³ to verify the operator observations. In addition, at 11 of the locations, the sediment was found to adhere to the probe upon removal, and the sediment texture was subsequently recorded. Two of the planned Trident locations for the 2005 event could not be measured because they were located above the river water level (i.e., on shore) at the time.

The interpreted distribution of offshore sediment textures based on the Trident observations, textures recorded in grab samples during the discharge mapping, and results from past sediment sampling events, are presented on Figures 3-6a–b, 3-7, and 3-8. A narrow nearshore zone of sandy sediments extends across the entire length of the site. Beyond this zone, the surface sediments trend to mixed sand and silt, and then to silt farther offshore. The nearshore sand zone is consistent with the projection to the river of the bottom of the surficial fill water-bearing zone that underlies the site (Figures 3-2b–c). The mixed sand/silt and silt zones are likely the expression of the alluvial deposit that underlies the fill water-bearing unit. The sand unit that underlies this deposit was not observed during either of the 2004 or 2005 investigations, but may daylight farther offshore.

Figures 3-6a–b, 3-7, and 3-8 present the Trident Probe results. Temperature (°C) and conductivity (mS/cm) data are presented as the difference between simultaneous readings in the river water column (taken 30 cm above the sediment mudline) and the saturated sediment (taken 60 cm below the sediment mudline). The results of the 2004 Trident work indicated temperature signals at locations ARC-03-B and ARC-06-B that could be indicative of groundwater discharge. These locations were selected for transition-zone water sampling during the pilot study based on the Trident data and their position relative to the buried channel and the uplands LNAPL area. ARC-02-B was also selected as a pilot study sampling location with the objective of collecting information at a comparable distance from the shoreline,

³ An additional 24 Trident locations were successfully completed at the ARCO site during the 2004 pilot study.

where a more typical temperature signal was observed (Figures 3-6a–b). The 2005 ARCO Trident data displayed similar trends as those observed during the 2004 pilot study (Figures 3-7 and 3-8). Locations AR1-A, AR3-B, and AR5-B showed a fairly strong temperature signal, potentially indicating a higher relative groundwater discharge rate.

Seepage meters could not be deployed during the 2004 pilot study at the ARCO site due to conflicts with the site's barge schedule. However, seven seepage meters were deployed at ARCO during the 2005 event, focusing primarily on the nearshore areas where the shallow water-bearing zone is likely to discharge to the river.⁴ Results of the seepage meter measurements are summarized in the following section.

3.2.3. Seepage Meter Results

Seepage meters capable of recording time-series positive and negative flux were installed at four of the 2005 Trident locations offshore of the ARCO site: AR2-A, AR3-C, AR5-B, and AR7-B. The remaining three seepage meters were placed in the area evaluated during the 2004 pilot study, including one seepage meter placed at pilot study location ARC-06-B, where the temperature signal suggested groundwater discharge may be occurring. The seepage meter locations are designated ARSEEP 2A, ARSEEP 3C, ARSEEP 5B, ARSEEP 7B, ARSEEP 8, ARSEEP 9, and ARSEEP 10. Complete results of the seepage meter measurements are presented in Figures 3-9a–b; average and maximum observed fluxes at each location are also shown on Figures 3-7 and 3-8.

Location ARSEEP 8, the only seepage meter that could be placed in the nearshore sand zone, displayed a high seepage rate (average 14.2 cm/d, maximum 74.3 cm/d). Although somewhat lower, the seepage rate recorded in the mixed sand/silt at location ARSEEP 2A was also strongly positive (average 5.3 cm/d, maximum 35.1 cm/d). The seepage rates recorded at the remaining five locations ranged, on average, from slightly positive to slightly negative (Figures 3-9a–b), indicating that these locations are not areas of significant groundwater discharge.

3.2.4. Discharge Mapping Summary

The combined lines of evidence suggest that groundwater and chemical migration associated with the ARCO site primarily occurs in the shallow fill zone underlying the site. Further, the data indicate that discharge of this shallow groundwater is likely occurring primarily in the permeable sediments present immediately adjacent to the

⁴ Due to low river water levels at the time of both the 2004 and 2005 field events, the narrow nearshore sand zone was often dry or in very shallow water. As a result, at several locations, Trident Probe and seepage meter measurements often could not be placed within the nearshore sand zone expected to be connected to the upland shallow water-bearing zone. Instead, measurements were taken as close to shore as reasonably feasible.

site shoreline. Discharge of site COIs is most likely to occur immediately offshore of the two LNAPL source zones, where COIs are most concentrated in groundwater.

3.3. TRANSITION ZONE WATER AND BULK SEDIMENT SAMPLING PLAN

Figure 3-10 presents the planned transition zone water sampling locations. A total of ten to eleven transition zone water samples will be collected from seven to eight locations. At each location, a sample will be collected within the top 30 cm of the sediments. A second sample will be collected from a target depth of at least 90 cm (up to 150 cm, if possible) at three of the locations. The rationale for the sampling locations is as follows:

- Samples will be collected from three to four nearshore locations (AR-01-A, AR-02-A, AR-03-A, and AR-04-B) in the nearshore sand and mixed sand/silt zones offshore of the northernmost LNAPL source area. Locations AR-02-A is the position (ARSEEP 2A) where seepage meter results indicate significant discharge. Locations AR-01-A and AR-04-B are located upstream and downstream of AR-02-A. Paired samples at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be collected at AR-01-A and AR-02-A. The fourth sampling location, AR-03-A, will be sampled by small-volume peepers in the event all the other locations are successfully sampled by the Trident. This specification was added in accordance with the conditional approval letter from EPA, dated 10/13/05 (EPA 2005).
- Samples will be collected from four locations in the nearshore sand zone offshore of the site. Paired 30-cm and 60-cm samples will also be collected at location R2-AR-2, where the highest seepage rate was recorded at the site. A 30-cm sample will be collected at locations R2-AR-1, R2-AR-3, and R2-AR-4 to provide additional coverage of the nearshore sand zone in areas offshore of the primary zones of uplands groundwater COIs of the site.

It is anticipated that the majority of the samples will be collected using the Trident Probe. Small-volume peepers will be used at any locations where the recovery (flow and/or volume) of the transition zone water by the Trident Probe is found to be inadequate. Replicate and equipment blank QC samples will be collected in accordance with the specifications prescribed in the QAPP supplement (Integral 2005d).

Figure 3-10 also depicts the locations where bulk sediment samples will be collected (AR-02-A, R2-AR-1, R2-AR-2 and R2-AR-4) to address sediment characterization data gaps in the vicinity of transition zone water sampling locations. The sediment samples will be collected from transition zone water sampling locations where bulk sediment chemistry data are not available for a similar sediment type located within approximately 50 ft, or where there is the potential for a more localized discharge (e.g., AR-02-A and R2-AR-2). Round 2 sediment sampling locations are shown on

Figure 3-10 for reference, and locations where VOC analyses and/or toxicity bioassays were conducted are indicated in unique colors.

Table 3-2 summarizes the analytes for the transition zone water and sediment samples.

4. RHONE POULENC

4.1. SITE HYDROGEOLOGY AND COI MIGRATION

The Rhone Poulenc site is a former chemical manufacturing facility located at river mile 7.2, approximately 2,000 ft southwest from the Willamette River (Figure 4-1). Groundwater at the Rhone Poulenc site occurs in three hydrogeologic zones: the fill/shallow alluvium zone, the alluvium zone, and the basalt zone. The groundwater flow direction is generally north and northeast toward the river. Figures 4-1 and 4-2a–c depict the potentiometric surface and geologic cross-sections at the Rhone Poulenc site. There is a potential preferential pathway for groundwater flow through the gravel zone at the base of the alluvium. Via this pathway, groundwater may flow north-northeast toward the river and/or migrate north-northwest at depth beneath the adjacent Siltronic site, following the bedrock slope in that direction as shown on cross-section E-E' (Figure 4-2c).

Subsurface NAPL [primarily dense nonaqueous phase liquid (DNAPL)] is likely an ongoing source of COIs to groundwater at the site, including VOCs, herbicides, and several metals. In nearshore upland areas downgradient from the Rhone Poulenc site, groundwater COIs have been observed primarily in the alluvium zone. As shown in Figure 4-3a–f, COIs have also been observed in the basalt zone; however, the basalt does not outcrop in the river and is therefore not expected to represent a groundwater discharge pathway to sediments. Figures 4-4a–l present the most recent groundwater concentration data⁵ for upland wells on Rhone Poulenc cross-sections.

Based on this understanding of the site, the alluvium zone discharge to the river at the Rhone Poulenc site is the primary pathway of concern for the Round 2 Groundwater Pathway Assessment. Findings of the groundwater discharge mapping work, performed to further investigate groundwater discharge to the river, are presented in the following section. A detailed discussion of the Rhone Poulenc site is presented in Appendix A-6 of the SAP (Integral et al. 2005).

4.2. ROUND 2 GROUNDWATER DISCHARGE MAPPING

The groundwater discharge mapping effort at the Rhone Poulenc site included stratigraphic coring, transect-based discharge mapping (temperature and conductivity measurement using the Trident Probe), collection of screening samples of transition zone water, and discharge verification measurements using seepage meters.

⁵ Note: All data for the cross-section plots were taken from Appendix A of the Groundwater Pathway Assessment SAP (Integral et al. 2005).

4.2.1. Stratigraphic Coring Results

A total of seven stratigraphic cores (plus one replicate core) were collected offshore of the Rhone Poulenc site to improve the understanding of the offshore stratigraphy. Figure 4-5a shows the location of the cores. Core logs are presented on Figures 4-5b–i. Core logs were used to update cross sections A-A' and C-C', as shown on Figures 4-2a–b. Core logs B1 through B4 and B8, all show gravel at depths below the mudline ranging from 2 to 10 ft. More nearshore borings (B5 and B9) show slightly more sediment over the gravel, with gravel being encountered at roughly 15 ft below the mudline. The cores generally showed a surficial silt layer ranging in thickness from 2 to 11 ft, with occasional sand layers below. All core logs and updated cross-sections compare well with the updated sediment surface texture maps.

4.2.2. Trident Results

The Trident Probe temperature and conductivity data, as well as relevant field observations (e.g., sediment texture), are summarized in Table 4-1. Temperature and conductivity mapping locations and results are shown on Figures 4-6 and 4-7. The groundwater discharge mapping effort spanned the entire shoreline, extending to the offshore area of the Arkema site upstream and well into the offshore area of the Siltronic site downstream. The sediment texture offshore of the Rhone Poulenc site was also recorded at each Trident location based on the resistance felt by the operators during the installation of the Trident Probe (Table 4-1). Confirmation surface sediment core samples (1-2 ft) were collected at four of the 49 successfully completed Trident Probe locations to verify the operator observations. In addition, at 25 locations, the sediment was found to adhere to the probe upon removal, and the sediment texture was subsequently recorded. Four proposed Trident locations could not be evaluated due to their proximity to the shipping channel and dangers associated with boat traffic (3 locations) or due to refusal at the mudline by gravel (1 location).

Figures 4-6 and 4-7 present the interpreted distribution of offshore sediment textures based on the Trident observations, grab samples, and from past sediment sampling events. In general, the nearshore area consists of sand, which becomes increasingly silty farther from shore. A sandy outcrop area is observed offshore along transects RP2 and RP3.

Figures 4-6 and 4-7 present the Trident Probe results. Temperature (°C) and conductivity (mS/cm) data are presented as the difference between simultaneous readings in the river water column (taken 30 cm above the sediment mudline) and the saturated sediment (taken 60 cm below the sediment mudline). The Rhone Poulenc Trident data indicate a noteworthy temperature signal (increased temperature signal relative to those recorded on the same transect or in the same sediment texture zone) located at RP3-C. The remaining Trident data indicate two other areas with noteworthy, though somewhat more subtle temperature signals – the areas around RP1-C and RP7-B. Seepage meters were placed at each of these three locations for

verification as well as at locations in different texture zones to determine relative flow in each of these major zones.

4.2.3. Seepage Meter Results

Seepage meters capable of recording time-series positive and negative flux were installed at 10 of the Trident locations offshore of the Rhone Poulenc site: RP1-C, RP2-D, RP3-A, RP3-C, RP3-E, RP4-D, RP6-D, RP7-B, RP8-B, and RP9-C. These seepage meter locations are designated RPSEEP 1C, RPSEEP 2D, RPSEEP 3A, RPSEEP 3C, RPSEEP 3E, RPSEEP 4D, RPSEEP 6D, RPSEEP 7B, RPSEEP 8B, and RPSEEP 9C. Complete results of the seepage meter measurements are presented in Figure 4-8; average and maximum observed fluxes at each location are also shown on Figures 4-6 and 4-7.

At all three locations with noted Trident temperature signals, positive average seepage records were observed. RP3-C, in particular, had a very high positive seepage flux, averaging 14.0 cm/day. Location RP7-B was the next highest, averaging a positive flux of 4.8 cm/day. Lower discharge rates were observed from the silt and mixed sand and silt zones farther offshore of the site, with the exception of location RP4-D which had an average positive flux of 3.2 cm/d.

4.2.4. Screening Sample Results

Screening samples of transition zone water were collected with the Trident Probe at 10 locations at a depth of 60 cm below the sediment surface interface. Sampling locations were limited to sandier areas, where purge rates could be maintained above 20 mL/min without clogging the intake. Samples were analyzed for the full project suite of VOCs and select herbicides, including Silvex. Herbicides were not sampled at locations RP1-B, RP6-B, and RP8-B due to the inability to collect adequate volume for analysis (as a result of poorly conductive sediments). Figure 4-9 presents the results for select herbicides, BTEX, chlorobenzene, dichlorobenzene, trichloroethene (TCE) and its degradation products. These results are also listed in Table 4-2.

Screening sample results support Trident temperature mapping and seepage meter results. The highest concentrations of Silvex, chlorobenzene, dichlorobenzene, and vinyl chloride were all observed at RP3-C, where the strongest temperature signal was observed and the highest seepage meter discharge rates were measured. Elevated concentrations were also observed at RP2-E, which is located in the same sandy zone as RP3-C, and at RP7-B, where Trident and seepage meter results also indicated positive groundwater flux. Very low to undetected concentrations were observed in samples collected farther offshore in the mixed sand and silt zone (RP5-E and RP1-E) as well as those from the central nearshore mixed sand and silt zone (RP4-A, RP5-A, RP6-B).

4.2.5. Discharge Mapping Summary

The combined lines of evidence indicate that an important focus area for sampling is the sandy zone along transects RP2 and RP3. Further, the core logs, positive flux measurements, and screening sample results all indicate that groundwater COIs may discharge at a more shallow depth than previously anticipated, potentially due to upwelling through more conductive sediments near the shore. Further, discharge mapping results suggest that the areas of silt and mixed sand and silt farther offshore near the edge of the channel are not likely major pathways for groundwater discharge.

4.3. TRANSITION ZONE WATER AND BULK SEDIMENT SAMPLING PLAN

Figure 4-10 presents the planned transition zone water sampling locations. A total of 11 transition zone water samples will be collected from eight locations. At each location, a sample will be collected within the top 30 cm of the sediments. A second sample will be collected from a target depth of at least 90 cm (up to 150 cm, if possible) at three of the locations. The rationale for the sampling locations is as follows:

- Samples will be collected from four locations in the area identified as surficially sandy along transects RP2 and RP3, where the texture, Trident measurements, seepage results, and screening sample results all indicate groundwater discharge. These sampling locations are labeled RP-02-E,⁶ R2-RP-1, RP-03-C, and RP-03-E. Paired samples at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be collected at RP-02-E and RP-03-C, where the screening sample results directly indicated the presence of groundwater COIs, as well as at RP-03-E.
- Two samples (R2-RP-2 and R2-RP-3) will be collected in the nearshore sandy area. This area is closer to shore than the area where Trident or seepage meter work was performed during discharge mapping, and was selected for sampling based on the indication of possible upwelling of COIs through more conductive zones. Additionally, during the Trident work, seepage of a milky white substance, possibly indicative of chlorinated solvents, was observed at the shoreline during low tide at the location corresponding to R2-RP-3.
- A sample will be collected at RP-07-B, which corresponds to the location of positive net discharge seepage meter results as well as observation of groundwater COIs in the screening sample.
- A sample will also be collected at RP-07-E/F⁶ in accordance with the EPA letter of conditional approval, dated 10/13/05 (EPA 2005).

It is anticipated that the majority of the samples will be collected using the Trident Probe. Small-volume peepers will be used at any 30-cm location where the recovery

⁶ In accordance with the letter of conditional approval received by EPA on 10/13/05 (EPA 2005), RP-02-E and RP-07-E/F will be targeted as far offshore as practicable.

(flow and/or volume) of the transition zone water by the Trident Probe is found to be inadequate. Replicate and equipment blank QC samples will be collected in accordance with the specifications prescribed in the QAPP supplement (Integral 2005d).

Figure 4-10 also depicts the locations where bulk sediment samples will be collected (RP-03-C, R2-RP-3, and RP-07-B) to address sediment characterization data gaps in the vicinity of transition zone water sampling locations. The sediment samples will be collected from transition zone water sampling locations where bulk sediment chemistry data are not available for a similar sediment type located within approximately 50 ft. Round 2 sediment sampling locations are shown on Figure 4-10 for reference, and locations where VOC analyses and/or toxicity bioassays were conducted are indicated in unique colors.

Table 4-3 summarizes the analytes for the transition zone water and sediment samples.

5. WILLBRIDGE

5.1. SITE HYDROGEOLOGY AND COI MIGRATION

The Willbridge site consists of three adjacent, currently operating terminals for petroleum storage and transfer facilities (operated by Kinder Morgan, Chevron, and ConocoPhillips) located on the west bank of the river at approximately river mile 7.5 (Figure 5-1). A single, unconfined aquifer exists at the site in the dredge sand fill materials and underlying native alluvium. The native alluvium consists predominantly of silt, with some interbedded sand and silt/clay deposits (Figures 5-2a–b). Overall, due to the dominance of silt in the alluvium, the hydraulic conductivity of this unit likely limits groundwater flow, although limited interbedded layers of sand have been observed in the alluvium, which may represent local pathways for groundwater flow within the unit. Beneath the native alluvium is the basalt bedrock.

The groundwater gradient is generally east to northeast toward the river, with flow likely occurring predominantly in the higher conductivity sand fill. The contact between the sandy fill and underlying alluvium is near the elevation of the river (Figure 5-2a). Due to a silt ridge in the native alluvium near the river and parallel to the shoreline (Figure 5-2a), which may have been a natural levee for a former lake in the area or a feature of the former Holbrook Slough, the groundwater gradient is relatively flat nearshore over the downstream half of the site and steeper in the upstream part of the site, where the silt ridge may be discontinuous or breached.

LNAPL has been observed in numerous wells at all three facilities (Figure 5-3a), but does not appear to be present as a contiguous plume. Dissolved groundwater plumes contain BTEX (Figure 5-3b), PAHs (Figure 5-3c), and several metals generally associated with petroleum releases (Figures 5-3d–e depict the occurrence of lead and chromium). Nearshore BTEX and PAH plumes are located primarily beneath the Chevron and ConocoPhillips properties, while metals are present in groundwater beneath all three terminals. Figures 5-4a–f present the most recent groundwater concentration data⁷ for upland wells on Willbridge cross-sections.

Two preferential flow pathways associated with the Chevron and ConocoPhillips terminal areas are present in the upstream half of the site. The first is a former 27-inch wood stave stormwater outfall co-located with the former Holbrook Slough. The stormwater outfall was grouted in 1982 and replaced with a 60-inch stormwater outfall to the southeast, which is the second preferential pathway. A cutoff wall and recovery system were installed around the 60-inch outfall to intercept preferential groundwater plume migration in the area. Construction of a second cutoff wall is proposed at the shoreline in the area of the first preferential pathway.

⁷ Note: All data for the cross-section plots were taken from Appendix A of the Groundwater Pathway Assessment SAP (Integral et al. 2005).

Three seep areas are also present at the site: two near the Kinder Morgan dock, and one on the property line between the Chevron and ConocoPhillips terminals (see Appendix A-8, Figure 2). BTEX and PAHs have been detected in the seep on the property line between the Chevron and ConocoPhillips terminals. Metals, including mercury and zinc, have been detected at the two seeps near the Kinder Morgan dock.

Based on this information, potential discharge areas for groundwater-related COIs to the Willamette River include the nearshore areas along the shoreline of the site, with particular focus on the area between the Chevron and ConocoPhillips docks where groundwater gradients are higher, dissolved groundwater plumes are close to the shoreline, preferential pathways are documented, and a seep has been observed to contain groundwater COIs.

Findings of the discharge mapping work, performed to further investigate groundwater discharge to the river, are presented in the following section. A detailed discussion of the Willbridge site is presented in Appendix A-8 of the SAP (Integral 2005c).

5.2. ROUND 2 GROUNDWATER DISCHARGE MAPPING

The groundwater discharge mapping effort at the Willbridge site included stratigraphic coring, transect-based discharge mapping (temperature and conductivity measurement using the Trident Probe), and discharge verification measurement using seepage meters.

5.2.1. Stratigraphic Coring Results

A total of five stratigraphic cores were collected offshore of the Willbridge site to improve the understanding of the offshore hydrogeology. Locations of the cores are shown on Figure 5-5a. Core logs are presented on Figures 5-5b–f. Core GW-D3 stratigraphic information was added to cross section A-A', shown on Figure 5-2a.

All of the core logs show the presence of a thick silt unit extending from at or just below the mudline to a depth of 30-35 ft. This unit is consistent with the projection of the silt alluvium layer underlying the site into the river (Figure 5-2a) and with the predominance of silt indicated by the surface sediment texture (Figure 5-6). The silt unit was continuous at all of the core locations, with the exception of GW-D5, in which a 4-ft thick layer of sand w/silt was observed at a depth of 14 to 18 ft below the mudline. This sand layer may be a buried feature related to the former Holbrook Slough (see Supplemental Figure SAIC 2; SAIC 2004). A petroleum odor and moderate sheen was observed in this section of the core, suggesting the buried feature may be a pathway for groundwater transport.

The surface sediments at locations GW-D3, GW-D4, and GW-D5 all consisted of silt. A 1-ft-thick surficial sand layer overlying a 3-ft-thick clay layer was present at the surface of core GW-D1, and a 1-ft-thick surficial sand and gravel layer was present at GW-D2. Slight to moderate petroleum odors and/or sheen were recorded in the

surface sediments from cores GW-D2, GW-D3, and GW-D5. A basal layer of basalt gravel was encountered at 32 ft below the mudline in GW-D3, and a plug of basalt was observed at the bottom of core GW-D5 (29.5 ft below the mudline).

5.2.2. Trident Results

The Trident Probe temperature and conductivity data, as well as relevant field observations (e.g., sediment texture), are summarized in Table 5-1. Temperature and conductivity mapping locations and results are shown on Figures 5-6 and 5-7. The groundwater discharge mapping effort spanned the entire shoreline, extending both upstream and downstream of the site boundaries. The sediment texture offshore of the Willbridge site was also recorded at each Trident location based on the resistance felt by the operators during the installation of the Trident Probe (Table 5-1). Confirmation surface sediment core samples (1-2 ft) were collected at four of the 38 successfully completed Trident Probe locations to verify the operator observations. In addition, at 20 locations, the sediment was found to adhere to the probe upon removal, and the sediment texture was subsequently recorded. Four of the planned Trident locations could not be measured. Three of these locations were inaccessible (due to the presence of barges and/or pilings), while the fourth planned location was above the river stage at the time of the sampling.

Figures 5-6 and 5-7 present the interpreted distribution of offshore sediment textures based on the Trident observations, grab samples, and past sediment sampling events. The vast majority of the surface sediments were silt. At the upstream end of the site, a nearshore zone of sandy sediments was observed. This zone then transitioned to a significant zone of mixed sand and silt. A small, isolated zone of sand and silt was also observed at the downstream end of the site—extending approximately 50 to 150 feet from the shoreline.

Figures 5-6 and 5-7 also present the Trident Probe measurements. Temperature (°C) and conductivity (mS/cm) data are presented as the difference between simultaneous readings in the river water column (taken 30 cm above the sediment mudline) and the saturated sediment (taken 60 cm below the sediment mudline). The Willbridge Trident data indicate several general patterns. Nearshore silts showed generally minimal temperature and conductivity signals (i.e., temperature differences and conductivity differences). There were a few exceptions to this trend—most notably locations W4-C and W1-A. The two locations in the upstream sand zone showed strong temperature signals, as did several of the locations in the upstream mixed sand/silt zone. Location W2-B, in the downstream mixed sand/silt zone, displayed significant temperature signal as well.

Seepage meters were placed at locations W2-B, W4-C, W7-C, W9-A, W9-C, W10-C, and W12-A. These locations were selected to quantify groundwater discharge rates in areas where the Trident profiling indicates potential discharge, paying particular attention to the southeastern half of the site, including the area of the former Holbrook Slough.

5.2.3. Seepage Meter Results

Seepage meters capable of recording time-series positive and negative flux were installed at seven of the Trident locations offshore of the Willbridge Site: W2-B, W4-C, W7-C, W9-A, W9-C, W10-C, and W12-A. These seepage meter locations are designated WSEEP 2B, WSEEP 4C, WSEEP 7C, WSEEP 9A, WSEEP 9C, WSEEP 10C, and WSEEP 12A. Complete results of the seepage meter measurements are presented in Figure 5-8; average and maximum observed fluxes at each location are also shown on Figures 5-6 and 5-7.

Positive seepage meter flow averages were recorded at all but one location: WSEEP10C. This location is the farthest offshore location evaluated and is located on the outer edge of the upstream mixed sand/silt zone. A high seepage rate (maximum 65.3 cm/d, and average 13.6 cm/d) was recorded in the nearshore sand zone at location WSEEP 12A. Significant positive discharge was also observed at locations WSEEP 4C (average 3.9 cm/d), WSEEP 7C (average 2.7 cm/d), WSEEP 9A (average 7.1cm/d) and WSEEP 9C (average 2.8 cm/d). These results suggest that groundwater is discharging to nearshore sediments adjacent to the Willbridge site, particularly in the area offshore of the Chevron and ConocoPhillips terminals. Although positive, the seepage rate recorded at location WSEEP 2B (average 0.4 cm/d) was low relative to other locations evaluated offshore of the site, suggesting that this zone is a relatively minor groundwater discharge area.

5.2.4. Discharge Mapping Summary

The combined lines of evidence suggest that the shallow groundwater and associated COI discharge are likely occurring primarily in the nearshore area adjacent to the site and may be more significant in the southeastern half of the site. Groundwater flow patterns, upland COI distributions, and the groundwater discharge mapping and seepage meter results all suggest that groundwater discharge is occurring in this area. Further, this finding is consistent with a potential influence of the buried former Holbrook Slough on groundwater flow. The high seepage rate recorded at location WSEEP 12A in the nearshore sand located at the upstream end of the site suggests this is an area of significant groundwater discharge. However, this area is somewhat removed from the primary zone of groundwater COIs.

5.3. TRANSITION ZONE WATER AND BULK SEDIMENT SAMPLING PLAN

Figure 5-9 presents the planned transition zone water sampling locations. A total of 10 transition zone water samples will be collected from seven locations. At each location, a sample will be collected within the top 30 cm of the sediments. A second sample will be collected from a target depth of at least 90 cm (up to 150 cm, if possible) at three of the locations. The rationale for the sampling locations is as follows:

- Samples will be collected from four locations (W-06-A, W-07-C, W-09-A, and W-09-C) in the nearshore area adjacent to the southeastern half of the site, where groundwater COI discharge is thought to be most significant (see Section 5.2.4). A paired sample at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be collected at W-06-A, W-07-C and W-09-A.
- A sample will be collected from the upstream nearshore sand zone at location W12-A, where a very strong seepage rate was recorded. A second sample will also be collected from the sand zone at R2-W-1, in an area closer to the zone of known upland groundwater COIs associated with the site.
- One sample will be collected from the nearshore area adjacent to the northwestern half of the site at W-04-C, where significant positive seepage was recorded.

Because of the relatively high seepage rates generally recorded offshore of the Willbridge site, it is anticipated that the majority of the samples will be collected using the Trident Probe. Small-volume peepers will be used at any 30 cm sampling locations where the recovery of the transition zone water by the Trident Probe is found to be inadequate. Replicate and equipment blank QC samples will be collected in accordance with the specifications prescribed in the QAPP supplement (Integral 2005d).

Figure 5-9 also depicts the location where two bulk sediment samples will be collected (W-09-A and W-09-C) to address sediment characterization data gaps in the vicinity of transition zone water sampling locations. The sediment samples will be collected from transition zone water sampling locations where bulk sediment chemistry data are not available for a similar sediment type located within approximately 50 ft (e.g., W-09-C), or where there is the potential for a more localized discharge (e.g., W-09-A). Round 2 sediment sampling locations are shown on Figure 5-9 for reference, and locations where VOC analyses and/or toxicity bioassays were conducted are indicated in unique colors.

Table 5-2 summarizes the analytes for the transition zone water and sediment samples.

6. GUNDERSON

6.1. SITE HYDROGEOLOGY AND COI MIGRATION

The Gunderson site is an industrial facility located between river mile 8.5 to 9.2 on the west bank of the Willamette River (Figure 6-1). Round 2 Groundwater Pathway Assessment activities at the Gunderson site are focused on the northwest end of the site in an area termed “Area 1” in past site environmental investigations. In Area 1, the groundwater gradient is relatively flat as a result of ongoing pumping from remediation system extraction wells. The location of this remediation system and the potentiometric surface of the shallow groundwater system are depicted on Figure 6-1.

Figures 6-2a–c present geologic cross-sections at the Gunderson site. As indicated in these cross-sections, the general site stratigraphy consists of three geologic units: alluvium and younger terrace deposits, a gravel zone, and basalt bedrock. The alluvium is typically 30-40 ft thick in Area 1, but becomes significantly thicker toward the southeast (apparent maximum thickness of approximately 160 ft). The alluvium consists of alternating layers of predominantly silty material and predominantly sandy material varying in thickness from roughly 5 to 20+ ft. In Area 1, a predominantly silty layer comprises the upper sediment layer in the river. The gravel zone is primarily encountered as a north/south trending channelized feature in Area 1, where it overlies the basalt and may act as a preferential pathway. Based on cross-section F-F’ (Figure 6-2c), there is not a clear in-river discharge point for this potential preferential pathway.

Groundwater COIs associated with Area 1 of the Gunderson site include VOCs and metals. The primary VOCs include trichloroethane (TCA) and its degradation products and dichloroethene (DCE). Elevated concentrations of BTEX and PAHs also exist in uplands groundwater at the Gunderson site; however, these COIs are not associated with Area 1. Figures 6-3a–h depict concentrations of metals, TCA, DCE, total BTEX, toluene, and PAHs in groundwater across the entire site. Figures 6-4a–d present the most recent groundwater concentration data⁸ for upland wells on Gunderson cross-sections.

Preferential transport of chlorinated VOCs may be occurring in the deep gravel zone beneath Area 1. It appears this gravel zone likely extends under the river and possibly below the bottom of the channel; consequently, it is unclear where or whether this pathway would ultimately reach the river. In the alluvium above the gravel zone, the nominal gradient suggests a limited driving force for discharge of groundwater COIs to the sediment-surface water interface. Due to the elevated nearshore groundwater concentrations of COIs, however, it is reasonable to assume

⁸ Note: All data for the cross-section plots were taken from Appendix A of the Groundwater Pathway Assessment SAP (Integral et al. 2005).

that groundwater COIs may be present in the sediments resulting from pre-remedy migration and may be discharging at low rates.

Findings of the discharge mapping work, performed to further investigate groundwater discharge to the river, are presented in the following section. A detailed discussion of the Gunderson site is presented in Appendix A-9 of the SAP (Integral et al. 2005).

6.2. ROUND 2 GROUNDWATER DISCHARGE MAPPING

The groundwater discharge mapping effort at the Gunderson site included stratigraphic coring, transect-based discharge mapping (temperature and conductivity measurement using the Trident Probe), collection of screening samples of transition zone water, and discharge verification measurements using seepage meters.

6.2.1. Stratigraphic Coring Results

Two stratigraphic cores (E1 and E2) were collected offshore of the Gunderson site to improve the understanding of the offshore stratigraphy (Figure 6-5a). Core logs are presented on Figures 6-5b–c. Both cores logs indicated thick silt layers extending from the mudline and to a depth of 5.5 to 19 ft. This finding compares well with the surface sediment texture mapping results (shown on Figure 6-6 and discussed below), which show silt over the entire sediment surface offshore of Area 1. The deeper core, E1, allowed for an extension of cross-section F-F' farther into the river (Figure 6-5a). This extended cross section demonstrates that the gravel unit elevation continues to decrease with distance offshore. At E1, where the water depth was 30 ft, 19 ft of silt overlies the more conductive gravel and sand units. These findings further support the conceptual understanding that the gravel preferential pathway does not daylight into the river offshore of the site.

6.2.2. Trident Results

The Trident Probe temperature and conductivity data, as well as relevant field observations (e.g., sediment texture), are summarized in Table 6-1. Temperature and conductivity mapping locations and results are shown on Figures 6-6 and 6-7. The sediment texture offshore of the Gunderson site was also recorded at each Trident location based on the resistance felt by the operators during the installation of the Trident Probe (Table 6-1). Confirmation surface sediment core samples (1-2 ft) were collected at four of the 28 successfully completed Trident Probe locations to verify the operator observations. In addition, at 17 locations, the sediment was found to adhere to the probe upon removal, and the sediment texture was subsequently recorded. Seven proposed Trident locations could not be measured due to the proximity to the shipping channel and dangers associated with boat traffic (4 locations) or due to the presence of a parked barge blocking access (3 locations).

Figures 6-6 and 6-7 present the interpreted distribution of offshore sediment textures based on the Trident observations, textures recorded in grab samples during the discharge mapping, and results from past sediment sampling events. Based on this surface texture mapping, the entire study area offshore and downstream of Area 1 consists of predominantly silty surficial material. Gravel on top of the silt was observed just offshore of the Lakeside Industries dock at locations GN3-D and GN4-C.

Figures 6-6 and 6-7 present the Trident Probe results. Temperature ($^{\circ}\text{C}$) and conductivity (mS/cm) data are presented as the difference between simultaneous readings in the river water column (taken 30 cm above the sediment mudline) and the saturated sediment (taken 60 cm below the sediment mudline). Although the Gunderson Trident data indicate generally higher temperature differences in the upstream transects (GN5, GN6, and GN7), temperature differences across the site are generally low relative to those observed at other sites. The only location with a temperature difference greater than 4°C was GN5-A. Notably low temperature differences ($<1^{\circ}\text{C}$) were observed just offshore of the Lakeside Industries dock, where gravel was observed on top of the silt layer (likely introduced to stabilize bottom sediments at this high traffic location). Seepage meters were placed at locations where Trident measurements could not be taken (GN1-E and GN4-E) to verify that no discharge is occurring at these areas. Seepage meters were also deployed at locations in the path of the TCA plume, where temperature and/or conductivity differences indicated possible discharge or where verification of no discharge was desired. These results are discussed in the following section.

6.2.3. Seepage Meter Results

Seepage meters capable of recording time-series positive and negative flux were installed at six locations offshore of the Gunderson site: GN1-E, GN2-E, GN3-B, GN4-A, GN4-C, and GN4-E. These seepage meter locations are designated GNSEEP1E, GNSEEP2E, GNSEEP3B, GNSEEP4A, GNSEEP4C, and GNSEEP4E. Complete results of the seepage meter measurements are presented in Figure 6-8; average and maximum observed fluxes at each location are also shown on Figures 6-6 and 6-7.

The highest maximum discharge rate was observed at nearshore seepage meter location GNSEEP4A, with a maximum rate of 3.4 cm/d and an average rate of 1.3 cm/d. The three seepage meters deployed farthest offshore (GNSEEP1E, GNSEEP2E, and GNSEEP4E) measured seepage rates that varied slightly between positive and negative flux, averaging near zero. The location in the gravel just offshore of the Lakeside Industries dock, GNSEEP4C, indicated a small net negative discharge as did location GNSEEP3B. These results indicated that groundwater discharge through the thick silt layer is minimal. The only significant discharge in the path of the TCA plume is likely occurring in the nearshore area around GN4-A and possibly GN5-A, which had an even stronger temperature signal than GN4-A.

6.2.4. Screening Sample Results

Screening samples of transition zone water were collected with the Trident at 10 locations at a depth of 60 cm below the sediment water interface. Because all locations were primarily silty, sampling was attempted at silty locations contrary to the original plan to focus only on sandy areas. Notes were kept on achievable purge rates and sampling rates for consideration in conjunction with the analytical results. Samples were analyzed for the full project suite of VOCs. Results for chlorinated VOCs, including TCA, dichloroethane (DCA), TCE, DCE, and vinyl chloride are presented on Figure 6-9 and in Table 6-2. On Figure 6-9, locations where sampling flow rates were less than 20 mL/min are noted. At these locations, volatiles may have been lost during the sampling process due to slow filling of the sample containers. At each noted location on Figure 6-9, flow rates were less than or equal to 5 mL/min. All locations without this designation had sampling flow rates greater than or equal to 60 mL/min.

Screening sample results agree with Trident temperature mapping and seepage meter results. The only measurable concentrations of VOCs were observed at the nearshore locations GN4-A and GN5-A, which are in the projected path of the TCA plume. Two other locations, GN3-C and GN7-A, had adequate sample flow rates, but still showed no detected VOCs in the screening samples. The other six locations with undetected VOC results had very low sampling flow rates. While these low flow rates may have resulted in loss of volatiles during sampling, they are also indicative of the poorly conductive material in the zone being sampled.

6.2.5. Discharge Mapping Summary

All available lines of evidence, including the upland gradient, the sediment texture and core results, the Trident and seepage meter results, and the screening sample results, indicate that there is minimal groundwater discharge offshore of Area 1 at the Gunderson site. The area of interest identified by the discharge mapping work is the nearshore area in the projected path of the TCA plume around locations GN4-A and GN5-A. This is supported by seepage meter results and screening sample results. Additionally, there may be residual COIs (which migrated before operation of the remediation system) discharging at slow rates along the path of the TCA plume farther offshore, though seepage meter results suggest discharge is minimal.

6.3. TRANSITION ZONE WATER AND BULK SEDIMENT SAMPLING PLAN

Figure 6-10 presents the planned transition zone water sampling locations. Ten transition zone water samples will be collected from seven locations. At each location, a sample will be collected within the top 30 cm of the sediments. A second sample will be collected from a target depth of at least 90 cm (up to 150 cm, if possible) at three of the locations. The rationale for the sampling locations is as follows:

- Samples will be collected from four locations in and around the nearshore area, where positive discharge was measured and chlorinated VOCs were present in screening samples. These sampling locations are labeled GN-03-A, GN-04-A, GN-04-B, and GN-05-A. Paired samples at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be collected at GN-04-A and GN-05-A.
- Three samples will be collected farther offshore in the path of the TCA plume, where small positive discharges were observed and screening samples were not collected. These locations (R2-GN-1, GN-01-E, and GN-02-E) will be sampled to evaluate the potential for residual groundwater-related COIs from migration of the plume before installation of the remediation system. A paired sample at depths of 30 cm and at least 90 cm (up to 150 cm, if possible) will be attempted at GN-01-E.

The nearshore samples at GN-04-A and GN-05-A will likely be collected using the Trident Probe, considering the acceptable flow rates achieved during screening sample collection. Samples at GN-03-A and GN-04-B will be collected with small-volume peepers per agreement with EPA (2005). Small-volume peepers will also be used at any other 30 cm locations where the recovery of the transition zone water by the Trident Probe is found to be inadequate, a condition which will probably apply to the three offshore locations. Replicate and equipment blank QC samples will be collected in accordance with the specifications prescribed in the QAPP supplement (Integral 2005d).

Figure 6-10 also depicts the locations where bulk sediment samples will be collected (R2-GN-1, GN-01-E, GN-02-E, and GN-05-A) to address sediment characterization data gaps in the vicinity of transition zone water sampling locations. The sediment samples will be collected from transition zone water sampling locations where bulk sediment chemistry data are not available for a similar sediment type located within approximately 50 ft. Round 2 sediment sampling locations are shown on Figure 6-10 for reference, and locations where VOC analyses and/or toxicity bioassays were conducted are indicated in unique colors.

Table 6-3 summarizes the analytes for the transition zone water and sediment samples.

7. REFERENCES

EPA. 2005. Personal communication (letter of October 13, 2005, regarding conditional approval for Round 2 Groundwater Pathway Assessment Field Sampling Plan Addendum 2). U.S. Environmental Protection Agency, Portland, OR.

Integral. 2004. Portland Harbor RI/FS Field Sampling Plan, Groundwater Pathway Assessment Pilot Study. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA.

Integral. 2005a. Portland Harbor RI/FS Groundwater Pathway Assessment Sampling and Analysis Plan Attachment 1: Field Sampling Plan Groundwater Plume Discharge Mapping. IC05-0016. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA.

Integral. 2005b. Portland Harbor RI/FS Groundwater Pathway Assessment Sampling and Analysis Plan Attachment 2: Field Sampling Plan Transition Zone Water Sampling. Draft. IC05-0022. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA. (*The final revision of the July 2005 draft is anticipated in March 2006.*)

Integral. 2005c. Portland Harbor RI/FS Field Sampling Plan for Transition Zone Water Sampling: Addendum 1 Sampling Plans for ExxonMobil, Siltronic, Gasco, and Arkema. Draft. IC05-0029. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA. (*The final revision of the September 2005 draft is anticipated in March 2006.*)

Integral. 2005d. Portland Harbor RI/FS Groundwater Pathway Assessment Quality Assurance Project Plan Supplement to Addendum 3: Groundwater Pathway Assessment Transition Zone Water Sampling. Draft. IC05-0023. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA. (*The final revision of the July 2005 draft is anticipated in January 2006.*)

Integral. In press. Dioxin Analysis Attachment to the Supplement to QAPP Addendum 3. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA.

Integral, Kennedy/Jenks, and Windward. 2005. Portland Harbor RI/FS Groundwater Pathway Assessment Sampling and Analysis Plan. Draft. IC05-0013. Prepared for the Lower Willamette Group, Portland, OR. Integral Consulting Inc., Mercer Island, WA. (*The final revision of the April 2005 draft is anticipated in April 2006.*)

SAIC. 2004. Proposal for Source Control Measure, Chevron Willbridge Distribution Center. Prepared for ChevronTexaco, San Ramon, CA. SAIC, Portland, OR. DEQ WMCSR-NWR-94-06.